



# Electrodeposited Nano Co-P: Coating Development and Technology Insertion at NADEP-JAX

Diana Facchini, Integran Technologies Inc.

Ruben Prado, Naval Air Systems Command (FRCSE)

Keith Legg, Rowan Technology Group

SERDP/ESTCP Workshop

Surface Finishing and Repair Issues for Sustaining New Military Aircraft

Phoenix – February 27<sup>th</sup>, 2008

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>27 FEB 2008</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2008 to 00-00-2008</b>	
4. TITLE AND SUBTITLE <b>Electrodeposited Nano Co-P: Coating Development and Technology Insertion at NADEP-JAX</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Integran Technologies Inc.,1725 Washington Road, Suite 305,Pittsburgh,PA,15241-1209</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>Surface Finishing and Repair Issues for Sustaining New Military Aircraft Workshop, February 26-28, 2008, Tempe, AZ. Sponsored by SERDP/ESTCP.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>22</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

# History of Cr-Replacement Project

---

## Objectives

- Develop an environmentally benign advanced nanocrystalline based coating technology that:
  - Is compatible with conventional electroplating infrastructure
  - Meets or exceed the performance of hard chrome
  - Costs similar to or less than existing hard chrome processes
  - Will be applied to non-line-of-sight surfaces

## Progress

- SERDP Project #PP-1152
  - Nano Co-P developed and demonstrated at the lab scale
- ESTCP Project #PP-0411
  - Scaled up to industrial production & moved to depot (NADEP-JAX)
  - Performance testing (JTP) in progress

# nCoP Process & Properties

## Simply an electrodeposition process

- Plating Efficiency >90%
- High Deposition rates (0.002"- 0.008" per hour)
- 10x the plating rate of EHC
- 1/10th the power consumption at the same plating rate

		nCoP	Hard Chrome
<b>Hardness</b>		530-580 VHN	800-1200 VHN
<b>Ductility</b>	<i>Elongation</i>	2-7%	< 1%
<b>Abrasive Wear (Taber)</b>	<i>CS-17 wheels</i>	17-20 mg/1000 cycles	3 mg/1000 cycles
<b>Adhesive Wear (Pin-on-disc)</b>	<i>Volume wear loss</i>	5-6x10 <sup>-6</sup> mm <sup>3</sup> /Nm (Al <sub>2</sub> O <sub>3</sub> ball on nCoP disk)	9-11x10 <sup>-6</sup> mm <sup>3</sup> /Nm (Al <sub>2</sub> O <sub>3</sub> ball on Cr disk)
	<i>Coefficient of Friction</i>	0.5 (Al <sub>2</sub> O <sub>3</sub> ball)	0.7 (Al <sub>2</sub> O <sub>3</sub> ball)
<b>Corrosion</b>	<i>Salt Spray (1000 h)</i>	Protection rating 7	Protection rating 2

# Industrial Scale-up & Technology Transfer

# Industrial Scale-up

**Scaled-up process produces acceptable nanostructured coatings**



## **Integran Technologies**

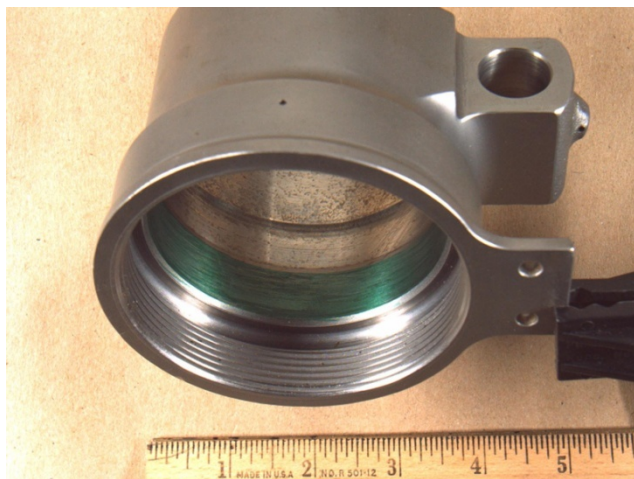
- 1300 L system
- In operation for 39 months
- No major issues to date

## **NADEP-JAX**

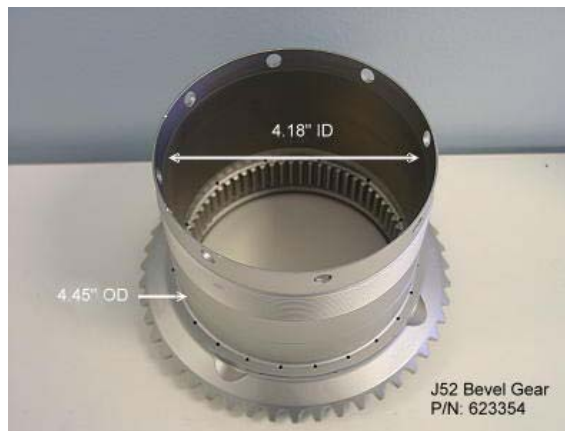
- 1100 L system
- In operation for 21 months
- Some growing pains – have been resolved

# Technology Transfer to NADEP-JAX

## Proposed Demo Parts to be Plated at NADEP-JAX



P-3 MLG Actuating Cylinder



J52 Bevel Gear

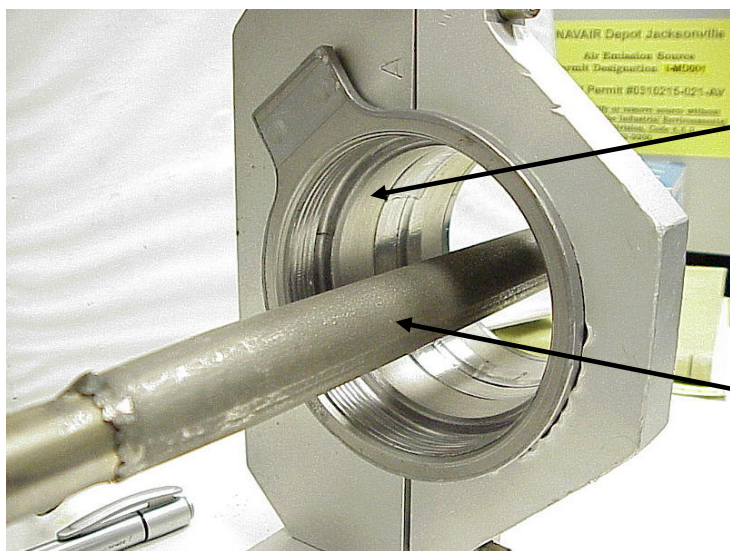


P3 MLG Cylinder Section,  
Axle Journal

# Technology Transfer to NADEP-JAX

## P-3 MLG Actuating Cylinder – Plating Trials

- 4340 steel
- Area to be plated: 5/8" band, 3" ID
- Cobalt anode rod



ID area to  
receive  
plating

Cobalt anode

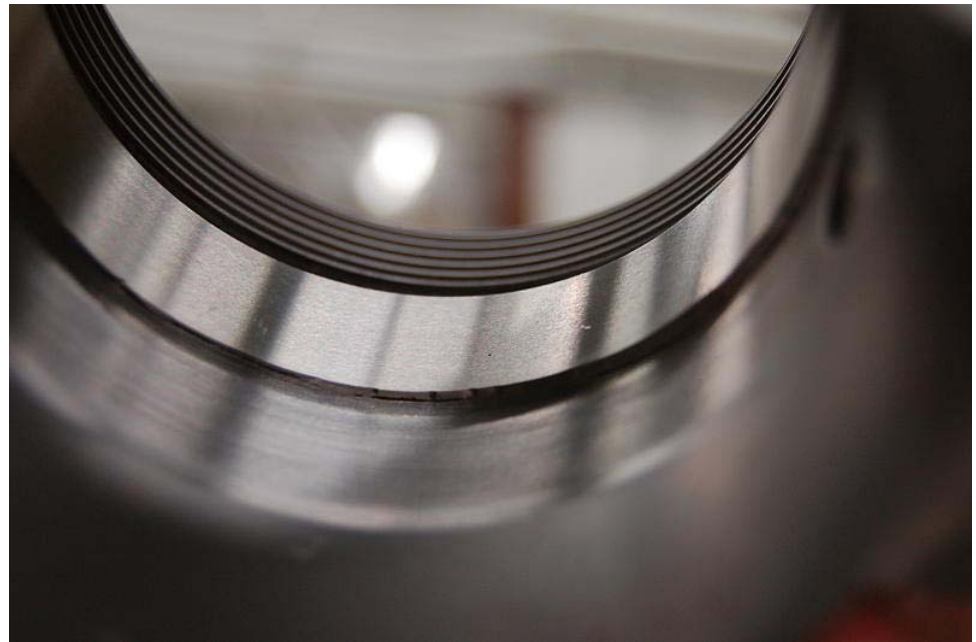


# Technology Transfer to NADEP-JAX

---

## P-3 MLG Actuating Cylinder – Plating Trials

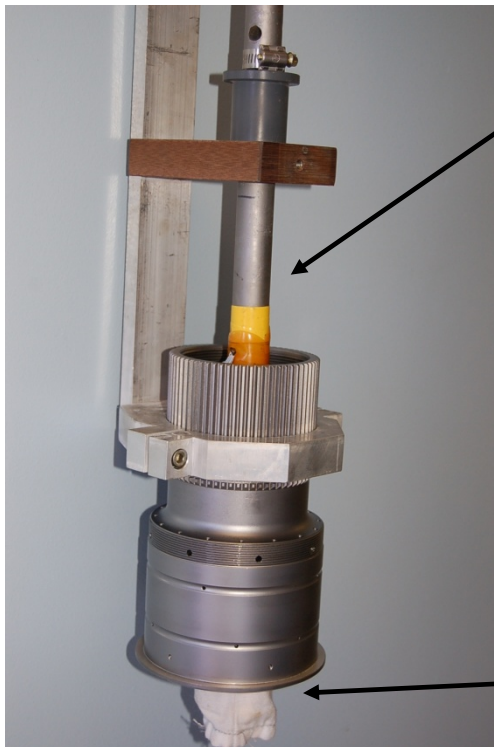
- Plating rate  $\sim 0.005''/\text{hr}$
- Thickness
  - 0.010'' (as-deposited)
  - 0.005'' (following grind)
- Good adhesion
- Visible pit after grinding



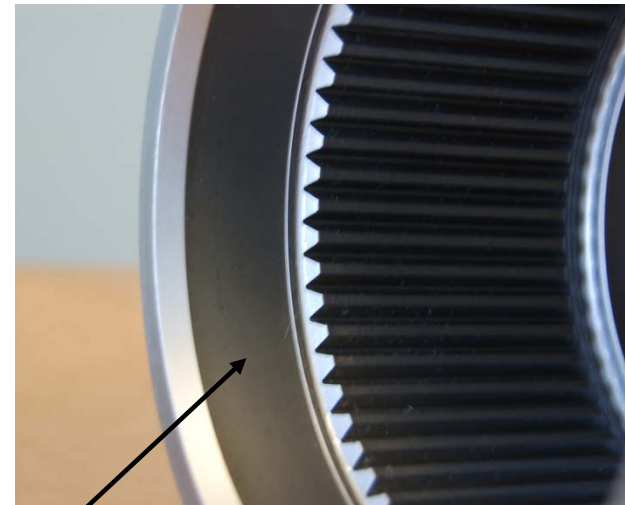
# Technology Transfer to NADEP-JAX

## J52 Coupling, Turbine Shaft Actuating Cylinder – Plating Trials

- 4340 steel
- 4.3" ID
- Anode basket



Demo part shown in rack assembly with anode basket in place

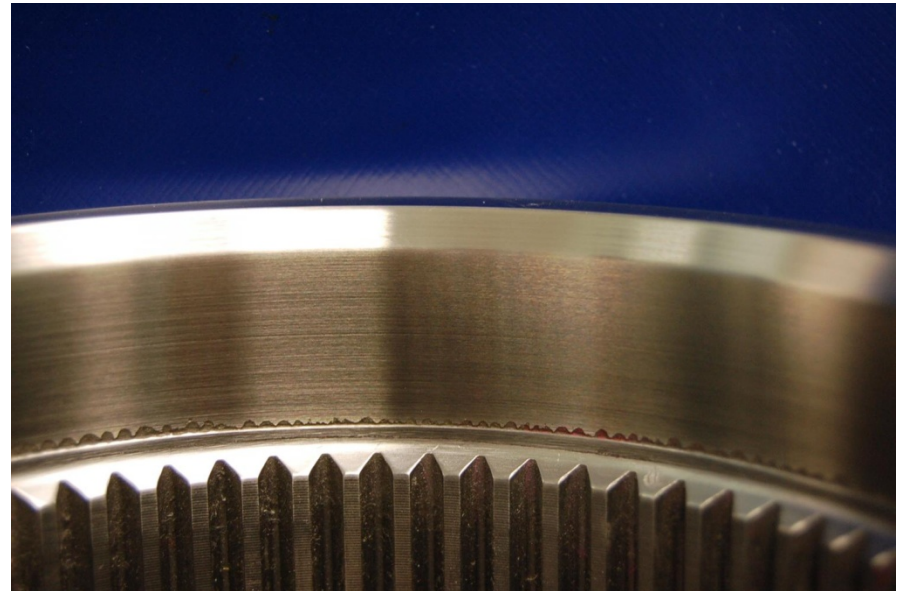


ID area to receive plating

# Technology Transfer to NADEP-JAX

## J52 Coupling, Turbine Shaft Actuating Cylinder – Plating Trials

- Plating rate ~ 0.0075"/hr
- Thickness
  - 0.015" (as-deposited)
  - 0.0075" (following grind)
- Good adhesion
- 4 Ra surface finish



# Joint Test Protocol (JTP)

# Performance Testing

---

## Adhesion

- demonstrated for 4340, 15-5PH, Aermet 100, 7075 Al

## Pre-test Grinding Study

- Mil-Std-866 acceptable for nCoP
- Finished to a 2-3 $\mu$ in roughness

## Fluid Immersion

- nCoP compatible with most service and overhaul fluids

## Corrosion (ASTM B117 & G85) & Rod-Seal Wear

- Samples prepared – testing pending

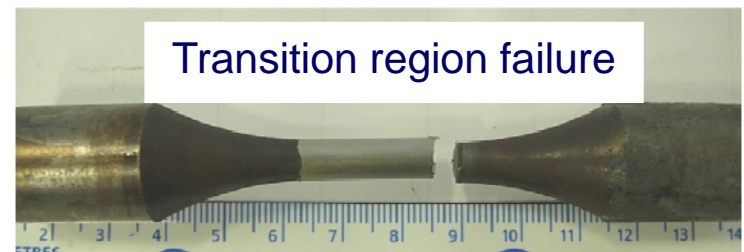
## Hydrogen Embrittlement

- Deposition parameters seem to affect test outcome
- To be resolved in follow-on study

# Performance Testing

## Axial Fatigue

- 0.003", 0.010" and 0.015" thick
- 4340, 15-5PH, 7075Al, Aermet 100 substrates
- Data showed debit compared to Cr
  - Found to be artefact of testing
- Post-test evaluation
  - Over 70% of bars failed at transition region (not on gage)
  - Due to high stress concentration (no runout)



**Prior fatigue data invalid – testing to be repeated**

# Follow-on Study

---

## **Repeat fatigue testing**

- Small scale study
- Obtain preliminary view of CoP fatigue performance

## **Re-evaluate process window**

- Previously optimized for hardness, composition, appearance, wear
- Current work will optimize for embrittlement

## **Data Acquisition**

- As required, re-evaluate properties using new deposition parameters

## **Producibility**

- Plate tube IDs & flat test specimens and evaluate

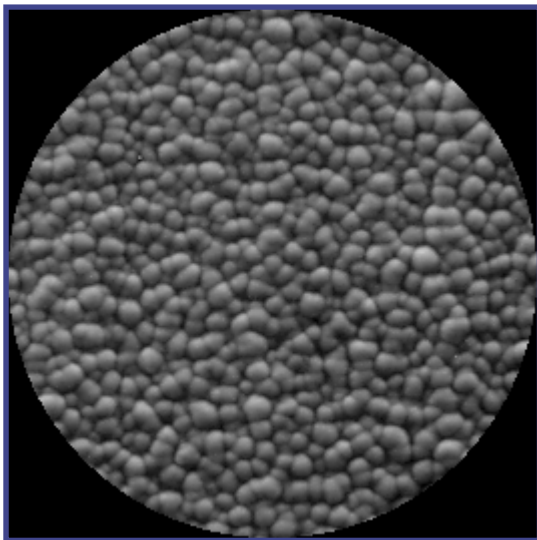
## **Cost benefit analysis**

## **Reporting**

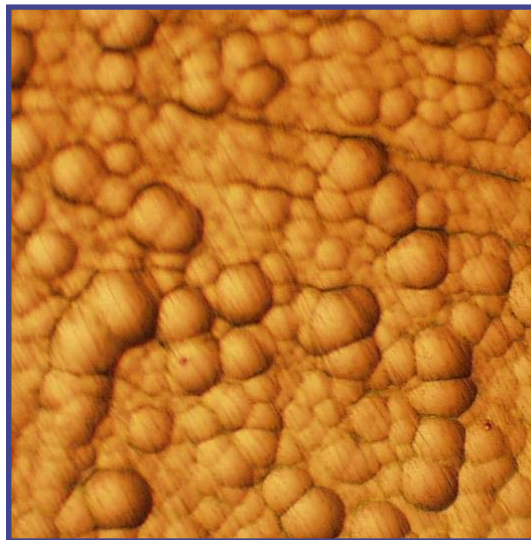
# Thin Dense Chrome (TDC) Alternative

# TDC Alternative Development

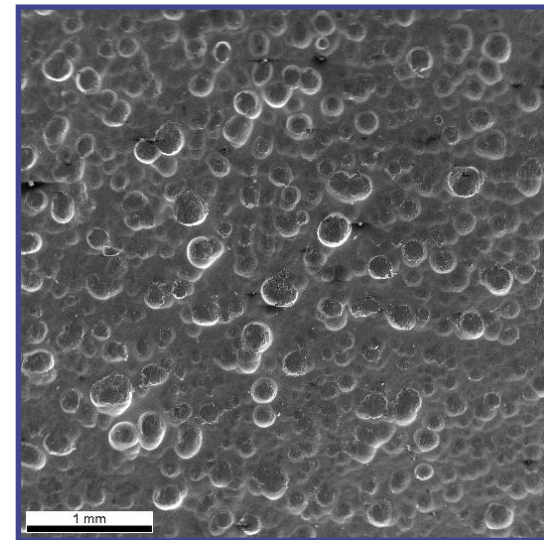
- Investigated Range of CoP Alloys (0-12wt%P)
- Benchmark comparison made against TDC (AMS 2438A)



**Thin Dense Chrome**



**CoP (low P)**



**CoP (high P)**

# TDC Alternative Properties

	<b>Class 1</b> nCoP (low P)	<b>Class 2</b> nCoP (high P)
<b>Application Types</b>	When corrosion resistance is required and the substrates cannot be HT	When corrosion resistance is not required and the substrates can be HT
<b>Surface Morphology</b>	Nodular (similar to TDC)	
<b>Thickness Uniformity</b>	Need proper masking/shielding to achieve	
<b>Surface Finish</b>	Unaltered after coating to 0.0005"	
<b>Adhesion</b>	Pass	Pass
<b>Ductility</b>	2-7%	~1%
<b>Salt Spray Corrosion</b>	Pass	Fail
<b>Hardness</b>	530-580 VHN	1000-1150 VHN
<b>Wear (Sliding)</b>	Good	Good
<b>Wear (Abrasive)</b>	17-20 mg/1000cycles	8-10 mg/1000cycles
<b>Hydrogen Embrittlement</b>	Pass (Type 1a2)	Not tested
<b>Fatigue</b>	Testing planned (Q2)	-

# Technology Commercialization

# Commercialization Status

## nCoP Development and Testing

	EHC replacement	TDC replacement
Process Development	✓	✓
Process Stability	✓	✓
Basic Property Testing	✓	✓
Advanced Property Testing	Q4	Q2

## New Product Introduction

	NADEP-JAX	Aerospace	Industrial Enduro	Other Industrial
Coupon Testing	✓	✓	✓	✓
Advanced Samples & Testing	In progress	✓	✓	✓
Deploy Dem/Val Tank	✓	`08	✓	`08
Production	TBD		✓	

**Looking for customers to participate in Dem/Val (2H08)**

# Commercial Deployments

---

## Example: Enduro Industries

- Hydraulic / Fluid Power Industry
- Carbon steel bars
- Cr replacement

### 1. Coupon Testing

- “Thin” coating – up to 1 mil
- No post plate grind or polish required
- Even distribution – to specifications

### 2. Advanced Samples & Testing

- Completed full performance testing for fluid power industry
- Tests include: salt spray, adhesion, sliding wear, elastomer seal wear, deflection testing, endurance testing with side loads

### 3. Commercial Scale Deployment

- As pictured at their facility

### 4. Production

- Material deployed with customers



# Summary

---

- **nCoP developed as alternative to EHC and TDC**
- **NADEP-JAX Dem/Val**
  - Demo parts plated successfully
- **JTP Testing**
  - Prior fatigue testing invalid
  - Follow-on study initiated
- **TDC Alternative Development**
  - Development and preliminary testing complete
  - Fatigue testing planned
- **Technology Commercialization**
  - Industrial deployments successful to date
  - New product testing and validation ongoing
  - Additional deployments planned

# The End

---

THANK YOU FOR LISTENING!